CENTRAL PIT CRATERS ON MARS: CHARACTERISTICS, DISTRIBUTIONS, AND IMPLICATIONS FOR FORMATION MODELS.

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Introduction: Central pit craters display a central depression either directly on the crater floor (in place of a central peak) or atop a central rise/peak. They are common on Mars, Ganymede, and Callisto but have not been identified on volatile-poor bodies such as the Moon and Mercury. Their presence on bodies with ice-rich crusts suggests that target volatiles are necessary for central pit formation. Several formation models have been proposed for central pits: release of impact-generated gases during crater formation [1], excavation into subsurface liquid layers [2], collapse of central peak [3], and coalescence of pits formed by impact melt-target ice interactions [4]. Analysis of the sizes, distributions, and general characteristics of central pit craters on Mars can provide constraints on these formation models.

Characteristics of Martian Central Pit Craters: Martian central pits are classified as floor pits (pit occurs directly on crater floor) and summit pits (pit occurs on central peak or other central rise) (Figure 1) Floor pits are further subdivided into symmetric or asymmetric pits, depending on pit shape.

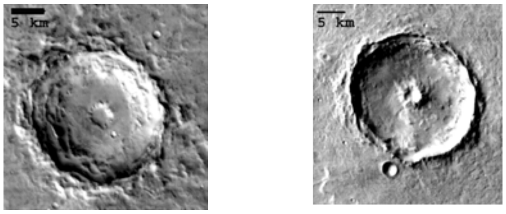

Figure 1: Examples of martian floor (left) and summit (right) pit craters

Using Viking, MOC, and THEMIS imagery, we have to date identified ~1600 central pit craters. Half of all central pit craters are symmetric floor pit (SY) craters while 41% are summit pit (sP) craters and 9% are asymmetric floor pit (AP) craters. While pit craters are seen on all terrains within the ±70° latitude range (Figure 2), strong concentrations are seen in the Xanthe, Margaritifer, and Arabia Terrae regions. There also seem to be concentrations of pit craters around the Tharsis and Elysium volcanoes. No strong regional variations in distribution are seen between floor and summit pit craters.

There also is no difference in occurrence of floor pits versus summit pits as a function of crater size—pit craters have diameters between 5 and 60 km (frequency peak near 13 km), suggesting excavation depths between ~1 km and 4.5 km based on standard depth-diameter relationships [5]. Central pit craters display a wide range of preservational states, from 2.0 (degraded) to 7.0 (pristine) [6, 7], indicating that the conditions favoring central pit formation have existed for most of the planet's history including up to the present. Those central pit craters fresh enough to display an ejecta blanket are typically associated with a multiple-layer ejecta morphology.

Comparison of the pit diameter (D_p) to the crater diameter (D_c) reveals that floor pits tend to be larger compared to their parent crater than summit pits (Figure 3). SY craters have D_p/D_c ranging between 0.07 and 0.28 with a median of 0.15. Summit pit D_p/D_c ranges between 0.05 and 0.19 with a median of 0.11.

On Ganymede, most central pits are superposed on an updomed crater floor, resulting from relaxation of the ice-rich crust after crater formation. We used MOLA topography to investigate whether martian floor pits are similarly located on updomed floors. Based on analysis of 485 floor pit craters in the northern hemisphere of Mars, we find no indication of floor updoming [8]. This suggests that the high crustal ice concentrations present on Ganymede and Callisto are not necessary to produce central pits. The ~20% crustal ice concentration estimated from layered ejecta studies [9, 10] is consistent with the lack of crater floor updoming.

Implications for Pit Formation Models: We can reject the model that central pits form by collapse of central peaks in weak target material [3]. The presence of summit pits on Mars and the occurrence of central peaks within the same diameter range and regions as central pit craters argues against this mechanism.

The model proposing layered targets with liquid layers at depth [2, 11] may have some support. The Xanthe, Margaritifer, and Arabia Terrae regions of Mars, where an abundance of central pit craters is seen, also display other geologic features (i.e., outflow channels, chaotic terrain) indicative of subsurface water and Arabia Terra has been proposed to be the site of a long-term subsurface aquifer [12]. Multiple layer ejecta has been proposed to result from excavation into subsurface liquid water reservoirs [13, 14], so the strong association of fresh central pit craters with this ejecta morphology may support the subsurface liquid layer formation model. The greatest problem with this model is the fact that central pit craters are seen practically everywhere on Mars. This suggests that subsurface liquid water layers exist within the upper 5 km on Mars everywhere on the planet. We are beginning to investigate whether there is a change in diameter of central pit craters with preservational state to determine if the depth to this potential liquid water reservoir has changed over time.

Vaporization of subsurface volatiles during crater formation [1], supported by high temperature gradients under the transient cavity in numerical simulations [15, 16], remains a viable mechanism for central pit formation. More investigation of coalescence of impact melt-generated pits on craters floors as a mechanism of central pit formation [4] is needed as additional HiRISE imagery becomes available.

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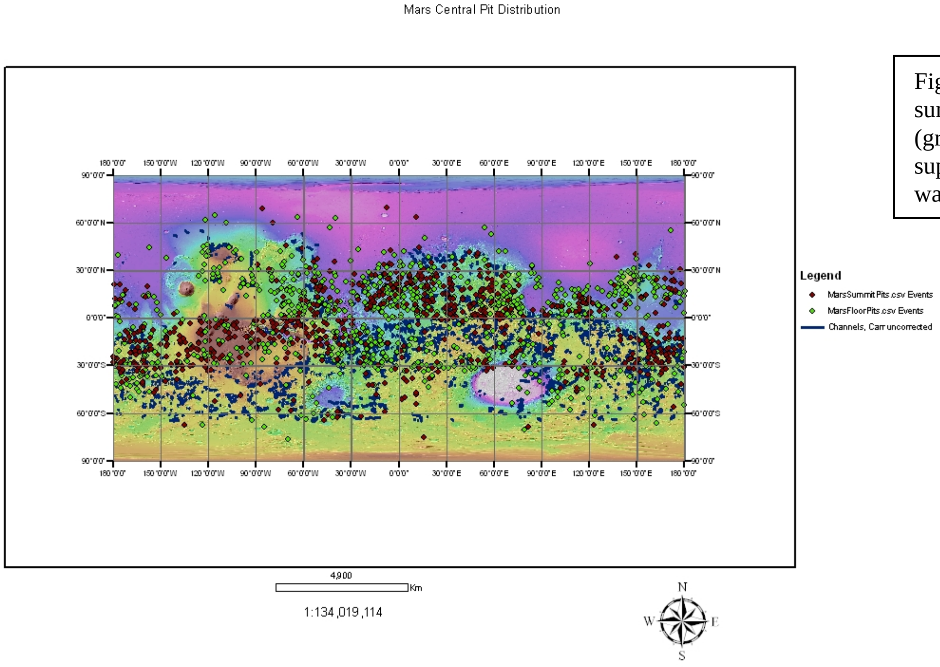

Figure 2: Distribution of summit (red) and floor (green) pit craters on Mars, superposed on the GRS water distribution map

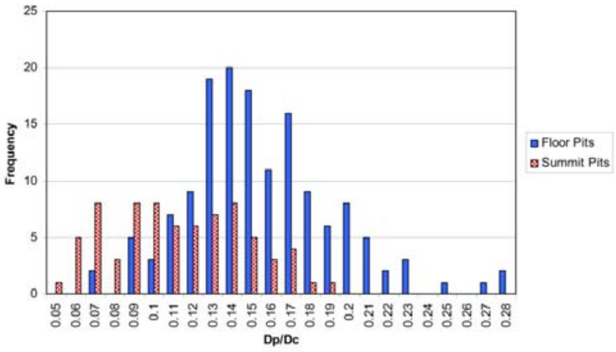

Figure 3: Ratio of pit diameter to crater diameter (D_p/D_c). Floor pits tend to be larger relative to their crater than summit pits.